DETAILED ACTION

1. This Office Action is in response to Applicant's amendment filed on 4/21/2009. Claims 3, 5 and 18 have been canceled. Claims 1, 2, 4, 6-9 and 13-17 have been amended. Accordingly, Claims 1, 2, 4 and 6-17 have been examined and are pending.

Response to Amendment

2. In response to Applicant's amendment, filed 4/21/2009, Examiner withdraws objection to duplication of claims 17 and 18, since claim 18 has been cancelled.

3. In response to Applicant's amendment, filed 4/21/2009, Examiner withdraws rejection under 35 U.S.C. §112, second paragraph of claims 1-9, 13, 14 and 16.

Claim Rejections - 35 USC § 103

4. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

5. Claims 1, 9, and 13-17 are rejected under 35 U.S.C. 103(a) as being unpatentable over Chu et al. *SCALABLE INFORMATION-DRIVEN SENSOR QUERYING AND ROUTING FOR AD HOC HETEROGENEOUS SENSOR NETWORKS*, The International Journal of High Performance Computing Applications, Vol. 16, No. 3, Fall 2002 (Chu), in view of Kuhn et al., *Asymptotically Optimal Geometric Mobile AdHoc Routing*, 6^{th} International Workshop on Discrete Algorithms and Methods

for Mobile Computing and Communications (DIALM) Atlanta, Georgia, September 28, 2002 (Kuhn)

6. Chu teaches the invention substantially as claimed including use of constraint-based routing for optimal path selection in ad-hoc sensor networks (see Abstract)

7. Regarding Claim 1, Chu teaches method of routing one or more information query from one or more arbitrary sensor network entry points in a network of sensor nodes to one or more destination nodes in a vicinity of physical phenomena of interest in the network, the method comprising:

selecting a destination node by computing a utility of a plurality of network sensor nodes and selecting a node with a highest utility to be the destination node wherein the computed utility indicates information gain (p.294, “Using information utility measures to optimize sensor selection and incremental belief update to combine information … is not new …The networks … actively seek out information, based on predictions of when and where ‘interesting’ events will be”)

establishing a leader node (p. 300, Fig 2 showing selection of leader node based on belief state and sensor selection algorithm);

using a multiple step lookup procedure to determine an optimum path between the leader node and the destination node (p. 300 Block 4 of Fig. 2 showing iterative updating of selected nodes);

routing the information query to a destination node based on the determined optimum path (p. 301, "The Information-Driven Sensor Query algorithm provides us with a way of selecting the optimal order of sensors to provide maximum incremental information gain"; p. 301ff. §3.2 "[T]he composite objective function [is used] to dynamically determine the optimal routing path")

a locus of all paths from a current node to the destination node forms an ellipse, the ellipse is sampled with four candidate points, and a maximum utility among four paths corresponding to the four candidate points is used as an estimate of utility of the ellipse (p. 295, §2.2 Sensor Selection "Figure 1 illustrates the basic idea of optimal sensor selection. The illustration is based upon the assumption that estimation uncertainty can be approximated by a Gaussian distribution, illustrated by uncertainty ellipsoids in the state space"; p.303, §4.1, Sensor Selection, "The information which is utilized to compute the next sensor to query is the belief state and sensor characteristics. We have four different criteria for choosing the next sensor")

Chu does not teach:

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point

Kuhn teaches:

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point (pp. 4-5 as shown in Fig. 5, 6 "Bounded Face Routing (BFR[$\hat{C}_d$]) Let $\boldsymbol{\varepsilon}$ be

the ellipse which is defined by the locus of all points the sum of whose distances from [source] s and [destination] t is $\hat{C}_d$, i.e. $\boldsymbol{\varepsilon}$ is an ellipse with foci [source] s and [destination] t)

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Kuhn regarding selection of points in the optimum path from within an elliptical region based on the source and destination as focal points, with the teachings of Chu regarding sensor selection based on the assumption of using an elliptical shape for optimal sensor selection (p. 295, §2.2 Sensor Selection)

One would have been motivated to do so in order to since Kuhn merely confirms the assumption of Chu regarding optimal path selection (Kuhn: p. 5 "[T]he best path from [source] s to [destination] t ... is completely inside or on [the ellipse] $\boldsymbol{\varepsilon}$")

8. Regarding Claim 9, Chu teaches a method of routing a query about the location of an event of interest via a network of sensor nodes, comprising:

determining a source node (p. 300, Fig 2 showing selection of leader node based on belief state and sensor selection algorithm);

establishing a neighborhood around the source node (p.301-302, "[T]he information query is directed by local decisions of individual sensor nodes and guided into regions satisfying the constraints defined by M(c)... The local decisions can be based upon different criteria, [e.g.]: For each sensor located at x(k), evaluate the objective function M(c) at the positions of the m sensors within a local neighborhood

determined by the communication distance, and pick the sensor j that minimizes the objective function locally within the neighborhood")

determining costs associated with communication that has already occurred along paths to neighborhood nodes and costs associated with going forward along paths to neighborhood nodes (p.295, "In order to compute the belief based on measurements from several sensors, we must pay a cost for communicating that information ...Given the current belief state, we wish to incrementally update the belief by incorporating measurements of previously not considered sensors [going forward]", wherein it is noted that the cost is incorporated into the current belief state (p. 296, col1/par. 2));

determining information gain based on neighborhood network sensor nodes already visited for a number of paths and to be visited for a number of paths (p.301 "Information-Driven Sensor Query algorithm provides us with a way of selecting the optimal order of sensors to provide maximum incremental information gain."; p. 295 "Given the current belief state, we wish to incrementally update the belief by incorporating measurements of previously not considered sensors [going forward]", wherein it is noted that information gain is incorporated into the current belief state (p. 296, col 1/par. 3));

forming a belief state about the event location based on the determined communication costs and determined information gain (p. 293 "[E]ach node can evaluate an information/cost objective, make a decision, update its belief state, and route data based on the local information/cost gradient and end-user requirement.");

routing the query based on the belief state (p. 293 "[E]ach node can evaluate an information/cost objective, make a decision, update its belief state, and route data based on the local information/cost gradient and end-user requirement.")

wherein a locus of all possible paths from a current node to the destination node forms an ellipse, the ellipse is sampled with four candidate points, and a maximum utility among four paths corresponding to the four candidate points is used as an estimate of utility of the ellipse (p. 295, §2.2 Sensor Selection "Figure 1 illustrates the basic idea of optimal sensor selection. The illustration is based upon the assumption that estimation uncertainty can be approximated by a Gaussian distribution, illustrated by uncertainty ellipsoids in the state space"; p.303, §4.1, Sensor Selection, "The information which is utilized to compute the next sensor to query is the belief state and sensor characteristics. We have four different criteria for choosing the next sensor")

<u>Chu does not teach</u>:

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point

<u>Kuhn teaches:</u>

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as an other focus point (pp. 4-5 as shown in Fig. 5,6 "Bounded Face Routing (BFR[$\hat{C}_d$]) Let **ε** be the ellipse which is defined by the locus of all points the sum of whose distances from [source] s and [destination] t is $\hat{C}_d$, i.e. **ε** is an ellipse with foci s and t…")

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Kuhn regarding selection of points in the optimum path from within an elliptical region based on the source and destination as focal points, with the teachings of Chu regarding sensor selection based on the assumption of using an elliptical shape for optimal sensor selection

One would have been motivated to do so in order to since Kuhn merely confirms the assumption of Chu regarding optimal path selection (Kuhn: p. 5 "[T]he best path from [source] s to [destination] t … is completely inside or on [the ellipse] **ε**")

9. Regarding Claim 13, Chu teaches a method of information-directed query routing along a path from a source node to a destination node in a network of sensor nodes, comprising:

determining a path that is more efficient in terms of communication cost than other paths (p.293 §1, "[C]onstrained isotopic routing (CADR) [is use] to direct data routing and incrementally combine sensor measurements so as to minimize an overall cost function")

optimizing for utility along the path and routing the query based on the determined cost (p.293, "[D]ata [is routed] …so that information gain is maximized while latency and bandwidth consumption is minimized… [by using] information driven sensor querying (IDSQ) to optimize sensor selection and constrained anisotropic diffusion routing (CADR) to direct data routing and incrementally combine sensor measurements so as to minimize an overall cost function"; p.298 "[T]he objective

function for sensor querying and routing is a function of both information utility and cost of bandwidth and latency.").

a locus of all paths from a current node to the destination node forms an ellipse, the ellipse is sampled with four candidate points, and a maximum utility among four paths corresponding to the four candidate points is used as an estimate of utility of the ellipse (p. 295, §2.2 "Figure 1 illustrates the basic idea of optimal sensor selection. The illustration is based upon the assumption that estimation uncertainty can be approximated by a Gaussian distribution, illustrated by uncertainty ellipsoids in the state space"; p.303, §4.1, Sensor Selection, "The information which is utilized to compute the next sensor to query is the belief state and sensor characteristics. We have four different criteria for choosing the next sensor")

<u>Chu does not teach</u>:

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point

<u>Kuhn teaches:</u>

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point (pp. 4-5 as shown in Fig. 5, 6 "Bounded Face Routing (BFR[$\hat{C}_d$]) Let $\boldsymbol{\varepsilon}$ be the ellipse which is defined by the locus of all points the sum of whose distances from [source] s and [destination] t is $\hat{C}_d$, i.e. $\boldsymbol{\varepsilon}$ is an ellipse with foci [source] s and [destination] t)

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Kuhn regarding selection of points in the optimum path from within an elliptical region based on the source and destination as focal points, with the teachings of Chu regarding sensor selection based on the assumption of using an elliptical shape for optimal sensor selection

One would have been motivated to do so in order to since Kuhn merely confirms the assumption of Chu regarding optimal path selection (Kuhn: p. 5 "[T]he best path from [source] s to [destination] t ... is completely inside or on [the ellipse] **ε**")

10. Regarding Claim 14, Chu teaches a method of point-to-point routing of query information regarding a phenomenon of interest in a sensor network having a plurality of sensor nodes along a path from an arbitrary entry point node to an arbitrary exit point node, the method comprising:

establishing a leader node (p. 300, Fig 2 showing selection of leader node based on belief state and sensor selection algorithm);

maximally aggregating information about the phenomenon of interest along the path by estimating information expected to be gained from the entry node to exit point node (p.293, "[D]ata [is routed] ...so that information gain is maximized while latency and bandwidth consumption is minimized... [by using] information driven sensor querying (IDSQ) to optimize sensor selection and constrained anisotropic diffusion routing (CADR) to direct data routing and incrementally combine sensor

measurements so as to minimize an overall cost function"; p.301 "Information-Driven Sensor Query algorithm provides us with a way of selecting the optimal order of sensors to provide maximum incremental information gain.");

selecting a successor leader node based on the estimated information expected to be gained (p.295, Fig. 1, showing sensor selection based on information gain; p.299 §3.1 "[S]ensor selection [is performed] using an information-driven criterion");

routing the query based on the maximally aggregated information (p.298 "[T]he objective function for sensor querying and routing is a function of ...information utility")

wherein a locus of all paths from a current node to the destination node forms an ellipse, the ellipse is sampled with four candidate points, and a maximum utility among four paths corresponding to the four candidate points is used as an estimate of utility of the ellipse (p. 295, §2.2 "Figure 1 illustrates the basic idea of optimal sensor selection. The illustration is based upon the assumption that estimation uncertainty can be approximated by a Gaussian distribution, illustrated by uncertainty ellipsoids in the state space"; p.303, §4.1, Sensor Selection, "The information which is utilized to compute the next sensor to query is the belief state and sensor characteristics. We have four different criteria for choosing the next sensor")

<u>Chu does not teach</u>:

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point

<u>Kuhn teaches:</u>

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point (pp. 4-5 as shown in Fig. 5, 6 "Bounded Face Routing (BFR[$\hat{C}_d$]) Let **ε** be the ellipse which is defined by the locus of all points the sum of whose distances from [source] s and [destination] t is $\hat{C}_d$, i.e. **ε** is an ellipse with foci [source] s and [destination] t)

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Kuhn regarding selection of points in the optimum path from within an elliptical region based on the source and destination as focal points, with the teachings of Chu regarding sensor selection based on the assumption of using an elliptical shape for optimal sensor selection

One would have been motivated to do so in order to since Kuhn merely confirms the assumption of Chu regarding optimal path selection (Kuhn: p. 5 "[T]he best path from [source] s to [destination] t ... is completely inside or on [the ellipse] **ε**")

11. Regarding Claim 15 Chu teaches the method of claim 14,

wherein estimating the information expected comprises establishing and moving a frontier and iteratively expanding nodes on the frontier until the exit point node is reached (p. 299 §3, In "the dynamic belief carrier protocol, belief is successively handed off to sensor nodes closest to locations where "useful" sensor data are being generated"... [T]he current sensor node updates the belief with its measurement and sends the estimation to the next neighbor that it determines can best improve the

estimation"; p. 300 Block 4 of Fig. 2 showing iterative updating of selected sensor nodes)

12. Regarding Claim 16, Chu teaches the method of Claim 14, further comprising:

obtaining network node sensor measurements to refine target estimates (p.302 §3.2.3 "The estimate and the estimation uncertainty can be dynamically updated along the routing path... Since the information utility objective function along the path is monotonically increasing, the information provided by subsequent sensors is getting incrementally better towards the global optimum")

wherein the arbitrary exit point is a location of an event of interest (p.294, "The networks ... actively seek out information, based on predictions of when and where 'interesting' events will be".)

13. Claims 2, 4, and 6-8, and 10 are rejected under 35 U.S.C. 103(a) as being unpatentable over Chu and Kuhn in view of S. Edelkamp and J. Eckerle, *New Strategies in Learning Real Time Heuristic Search*, AAAI Technical Report WS-97-10, 1997, p.30-35 (Edelkamp)

14. Chu teaches the invention substantially as claimed including use of constraint-based routing for optimal path selection in ad-hoc sensor networks (see Abstract)

15. Regarding Claim 2, Chu teaches the method of claim 1, wherein the multiple step lookup procedure comprises:

determining a minimum number of hops required to reach the destination node from the leader node; selecting a minimum number of hops path that traverses nodes the sum of whose utilities is the greatest (p.293, "[D]irected diffusion [cite omitted] is …where the routing paths are established using the distance information between neighboring nodes to minimize the number of hops …. IDSQ/CADR can be considered as a generalization of directed diffusion routing …[which] uses both information gain and communication cost to direct the data diffusion"; wherein Examiner notes that "selecting a minimum number of hops path" implies "determining a minimum number of hops…" as a necessary pre-condition)

selecting a first node in the selected path and passing leadership from the leader node to the first node (p. 299 §3, In "the dynamic belief carrier protocol, belief is successively handed off to sensor nodes closest to locations where "useful" sensor data are being generated…"; p. 300 Block 4 of Fig. 2 showing iterative updating of selected nodes).

a locus of all paths from a current node to the destination node forms an ellipse, the ellipse is sampled with four candidate points, and a maximum utility among four paths corresponding to the four candidate points is used as an estimate of utility of the ellipse (p. 295, §2.2 Sensor Selection "Figure 1 illustrates the basic idea of optimal sensor selection. The illustration is based upon the assumption that estimation uncertainty can be approximated by a Gaussian distribution, illustrated by uncertainty

ellipsoids in the state space"; p.303, §4.1, Sensor Selection, "The information which is utilized to compute the next sensor to query is the belief state and sensor characteristics. We have four different criteria for choosing the next sensor")

Chu does not teach:

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point

determining all possible paths of the minimum number of hops or less from the current leader node to the destination node;

determining the utilities of all possible minimum number of hops paths

Kuhn teaches:

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point (pp. 4-5 as shown in Fig. 5, 6 "Bounded Face Routing (BFR[$\hat{C}_d$]) Let **ε** be the ellipse which is defined by the locus of all points the sum of whose distances from [source] s and [destination] t is $\hat{C}_d$, i.e. **ε** is an ellipse with foci [source] s and [destination] t)

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Kuhn regarding selection of points in the optimum path from within an elliptical region based on the source and destination as focal points, with the teachings of Chu regarding sensor selection based on the assumption of using an elliptical shape for optimal sensor selection (p. 295, §2.2 Sensor Selection)

One would have been motivated to do so in order to since Kuhn merely confirms the assumption of Chu regarding optimal path selection (Kuhn: p. 5 “[T]he best path from [source] s to [destination] t … is completely inside or on [the ellipse] **ε**”)

<u>Chu and Kuhn do not teach:</u>

determining all possible paths of the minimum number of hops or less from the current leader node to the destination node;

determining the utilities of all possible minimum number of hops paths

<u>Edelkamp teaches</u>:

determining all possible paths of the minimum number of hops or less from the current leader node to the destination node; [and] determining the utilities of all possible minimum number of hops paths (p.31 col.1, “The distance of one node to the set of goal nodes F is the minimum of the shortest path values for all g ε F. The most efficient approach … to find all shortest path values to set F is to put all goal nodes [(collection of shortest path values)] in the priority queue at once and to calculate the distances f to the set F dynamically" wherein Examiner notes that the “set of goal nodes F” includes the set consisting of a singular destination node)

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Edelkamp with regard to determining all of the minimum hop paths to the destination, with the teachings of Chu regarding optimal path calculation.

One would have been motivated to do so Edelkamp teaches a specific mechanism for determining an optimal path based on utility and cost incurred by traversing nodes to the destination.

16. Regarding Claim 4, Chu teaches a system to route information via a network of sensor nodes from a leader node to a destination node, comprising:

a destination node selection mechanism that determines the utility of a plurality of nodes and selects a node with the highest utility to be the destination node; wherein the determined utility indicates information gain (p.294, "Using information utility measures to optimize sensor selection and incremental belief update to combine information … is not new …The networks … actively seek out information, based on predictions of when and where 'interesting' events will be")

a path selection mechanism that selects an m-hop path that traverses the nodes the sum of whose utilities (information gain) is the greatest (p.293, "[D]ata [is routed] …so that information gain is maximized … [by using] information driven sensor querying (IDSQ) to optimize sensor selection…"; p.301 "Information-Driven Sensor Query algorithm provides us with a way of selecting the optimal order of sensors to provide maximum incremental information gain.");

a selection mechanism that selects a first node in the selected m-hop path and passes leadership from the leader node to the first node (p. 299 §3, In "the dynamic belief carrier protocol, belief is successively handed off to sensor nodes closest to

locations where "useful" sensor data are being generated…"; p. 300 Block 4 of Fig. 2 showing iterative updating of selected nodes).

a locus of all possible paths from a current node to the destination node forms an ellipse, the ellipse is sampled with four candidate points, and a maximum utility among four paths corresponding to the four candidate points is used as an estimate of utility of the ellipse (p. 295, §2.2 Sensor Selection "Figure 1 illustrates the basic idea of optimal sensor selection. The illustration is based upon the assumption that estimation uncertainty can be approximated by a Gaussian distribution, illustrated by uncertainty ellipsoids in the state space"; p.303, §4.1, Sensor Selection, "The information which is utilized to compute the next sensor to query is the belief state and sensor characteristics. We have four different criteria for choosing the next sensor")

<u>Chu does not teach</u>:

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point

determining all possible paths of the minimum number of hops or less from the current leader node to the destination node;

determining the utilities of all possible minimum number of hops paths

<u>Kuhn teaches:</u>

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point (pp. 4-5 as shown in Fig. 5, 6 "Bounded Face Routing (BFR[$\hat{C}_d$]) Let **ε** be

the ellipse which is defined by the locus of all points the sum of whose distances from [source] s and [destination] t is $\hat{C}_d$, i.e. **ε** is an ellipse with foci [source] s and [destination] t)

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Kuhn regarding selection of points in the optimum path from within an elliptical region based on the source and destination as focal points, with the teachings of Chu regarding sensor selection based on the assumption of using an elliptical shape for optimal sensor selection (p. 295, §2.2 Sensor Selection)

One would have been motivated to do so in order to since Kuhn merely confirms the assumption of Chu regarding optimal path selection (Kuhn: p. 5 "[T]he best path from [source] s to [destination] t … is completely inside or on [the ellipse] **ε**")

Chu and Kuhn do not teach:

determining all possible paths of the minimum number of hops or less from the current leader node to the destination node;

determining the utilities of all possible minimum number of hops paths

Edelkamp teaches:

determining all possible paths of the minimum number of hops or less from the current leader node to the destination node (shortest path values); [and] determining the utilities of all possible minimum number of hops paths (p.31 col.1, "The distance of one node to the set of goal nodes F is the minimum of the shortest path values for all g ϵ F. The most efficient approach … to find all shortest path values to set F is to put all goal nodes [(collection of shortest path values)] in the priority queue at once and to calculate

the distances f to the set F dynamically wherein Examiner notes that the "set of goal nodes F" includes the set consisting of a singular destination node)

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Edelkamp with regard to determining all of the minimum hop paths to the destination, with the teachings of Chu regarding optimal path calculation.

One would have been motivated to do so Edelkamp teaches a specific mechanism for determining an optimal path based on utility and cost incurred by traversing nodes to the destination.

17. Regarding Claim 6, Chu teaches the system of claim 4, further comprising:

a leadership transfer mechanism that changes leadership from one node to another node (p. 299 §3, In "the dynamic belief carrier protocol, belief is successively handed off to sensor nodes closest to locations where "useful" sensor data are being generated"... [T]he current sensor node updates the belief with its measurement and sends the estimation to the next neighbor that it determines can best improve the estimation"; p. 300 Block 4 of Fig. 2 showing iterative updating of selected nodes)

18. Regarding Claim 7, Chu teaches a point-to-point query routing method via a network of sensor nodes including a source sensor node and a destination sensor node, the method comprising:

establishing a neighborhood around the source node (p.301-302, "[T]he information query is directed by local decisions of individual sensor nodes and guided into regions satisfying the constraints defined by M(c)... The local decisions can be based upon different criteria, [e.g.]: For each sensor located at x(k), evaluate the objective function M(c) at the positions of the m sensors within a local neighborhood determined by the communication distance, and pick the sensor j that minimizes the objective function locally within the neighborhood")

determining costs associated with communication that has already occurred along paths to neighborhood sensor nodes and costs associated with going forward along paths to sensor nodes in the neighborhood of the source node (p.301 The objective function "M(c) is incrementally updated as the belief is updated along the routing path"; wherein M(c) includes associated costs);

determining utility based on neighborhood network nodes already visited for a number of paths and to be visited for a number of paths (p.301 The objective function "M(c) is incrementally updated as the belief is updated along the routing path"; wherein M(c) includes utility gain);

a locus of all possible paths from a current node to the destination node forms an ellipse, the ellipse is sampled with four candidate points, and a maximum utility among four paths corresponding to the four candidate points is used as an estimate of utility of the ellipse (p. 295, §2.2 Sensor Selection "Figure 1 illustrates the basic idea of optimal sensor selection. The illustration is based upon the assumption that estimation uncertainty can be approximated by a Gaussian distribution, illustrated by uncertainty

ellipsoids in the state space"; p.303, §4.1, Sensor Selection, "The information which is utilized to compute the next sensor to query is the belief state and sensor characteristics. We have four different criteria for choosing the next sensor").

Chu does not teach:

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point.

conducting an RTA* type forward search to relay from the entry point to the destination point based on the determined cost and information gain.

Kuhn teaches:

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point (pp. 4-5 as shown in Fig. 5, 6 "Bounded Face Routing (BFR[$\hat{C}_d$]) Let $\boldsymbol{\varepsilon}$ be the ellipse which is defined by the locus of all points the sum of whose distances from [source] s and [destination] t is $\hat{C}_d$, i.e. $\boldsymbol{\varepsilon}$ is an ellipse with foci [source] s and [destination] t)

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Kuhn regarding selection of points in the optimum path from within an elliptical region based on the source and destination as focal points, with the teachings of Chu regarding sensor selection based on the assumption of using an elliptical shape for optimal sensor selection (p. 295, §2.2 Sensor Selection)

One would have been motivated to do so in order to since Kuhn merely confirms the assumption of Chu regarding optimal path selection (Kuhn: p. 5 "[T]he best path from [source] s to [destination] t ... is completely inside or on [the ellipse] **ε**")

Chu and Kuhn do not teach:

conducting an RTA* type forward search to relay from the entry point to the destination point based on the determined cost and information gain.

Edelkamp teaches:

conducting an RTA* type forward search to relay from the entry point to the destination point based on the determined cost and information gain (p. 32,"The algorithm *SRTA** (real-time A* using signs) is similar to the *RTA** procedure where "improvement is based on signs that are assigned to each edge in the state space. Each sign is seen as a lower bound for the shortest path passing this edge")

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Edelkamp with regard to use of an RTA* type heuristic forward search with the teachings of Chu regarding computing an optimal route from a given source to the selected destination for an information query in an ad-hoc sensor network, since Edelkamp explicitly teaches using an RTA*-type forward search as a well-known heuristic in such systems.

19. Regarding Claim 8, Chu teaches a method of routing information about the location of an event via a network of sensor nodes including a leader node and a destination node, comprising:

selecting a destination location by computing the utility of a plurality of nodes and selecting a node with the highest utility to be the destination node; wherein the computed utility indicates information gain (p.294, "Using information utility measures to optimize sensor selection and incremental belief update to combine information ... is not new ...The networks ... actively seek out information, based on predictions of when and where 'interesting' events will be")

determining a minimum number of hops required to reach the destination location from a leader node (p.293, "[D]irected diffusion [cite omitted] is ...where the routing paths are established using the distance information between neighboring nodes to minimize the number of hops .... IDSQ/CADR can be considered as a generalization of directed diffusion routing ...[which] uses both information gain and communication cost to direct the data diffusion"; wherein Examiner notes that "selecting a minimum number of hops path" implies "determining a minimum number of hops..." as a necessary pre-condition)) ;

selecting a path that traverses the nodes the sum of whose utilities is the greatest (p.293, "[D]ata [is routed] ...so that information gain is maximized ...[by using] information driven sensor querying (IDSQ) to optimize sensor selection..."; p.301 "Information-Driven Sensor Query algorithm provides us with a way of selecting the optimal order of sensors to provide maximum incremental information gain.")

selecting a first node in the selected path and passing leadership from the leader node to the first node (p. 299 §3, In "the dynamic belief carrier protocol, belief is successively handed off to sensor nodes closest to locations where "useful" sensor data

are being generated…"; p. 300 Block 4 of Fig. 2 showing iterative updating of selected nodes)

a locus of all possible paths from a current node to the destination node forms an ellipse, the ellipse is sampled with four candidate points, and a maximum utility among four paths corresponding to the four candidate points is used as an estimate of utility of the ellipse (p. 295, §2.2 "Figure 1 illustrates the basic idea of optimal sensor selection. The illustration is based upon the assumption that estimation uncertainty can be approximated by a Gaussian distribution, illustrated by uncertainty ellipsoids in the state space"; p.303, §4.1, Sensor Selection, "The information which is utilized to compute the next sensor to query is the belief state and sensor characteristics. We have four different criteria for choosing the next sensor")

<u>Chu does not teach</u>:

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point

determining all possible paths of the minimum number of hops or less from the current leader node to the destination node

<u>Kuhn teaches:</u>

a locus of all possible paths from a current node to the destination node forms an ellipse with the destination node as one focus point and the current node as another focus point (pp. 4-5 as shown in Fig. 5, 6 "Bounded Face Routing (BFR[$\hat{C}_d$]) Let **ε** be the ellipse which is defined by the locus of all points the sum of whose distances from

[source] s and [destination] t is $\hat{C}_d$, i.e. $\boldsymbol{\varepsilon}$ is an ellipse with foci [source] s and [destination] t)

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Kuhn regarding selection of points in the optimum path from within an elliptical region based on the source and destination as focal points, with the teachings of Chu regarding sensor selection based on the assumption of using an elliptical shape for optimal sensor selection

One would have been motivated to do so in order to since Kuhn merely confirms the assumption of Chu regarding optimal path selection (Kuhn: p. 5 "[T]he best path from [source] s to [destination] t … is completely inside or on [the ellipse] $\boldsymbol{\varepsilon}$")

<u>Chu and Kuhn do not teach:</u>

determining all possible paths of the minimum number of hops or less from the current leader node to the destination node;

<u>Edelkamp teaches</u>:

determining all possible paths of the minimum number of hops or less from the current leader node to the destination node (shortest path values) (p.31 col.1, "The distance of one node to the set of goal nodes F is the minimum of the shortest path values for all g ϵ F. The most efficient approach … to find all shortest path values to set F is to put all goal nodes [(collection of shortest path values)] in the priority queue at once and to calculate the distances f to the set F dynamically" wherein Examiner notes that the "set of goal nodes F" includes the set consisting of a singular destination node)

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Edelkamp with regard to determining all of the minimum hop paths to the destination, with the teachings of Chu regarding optimal path calculation.

One would have been motivated to do so Edelkamp teaches a specific mechanism for determining an optimal path based on utility and cost incurred by traversing nodes to the destination.

20. Regarding Claim 10, Chu teaches the system of claim 4 wherein the sensor nodes comprise different types of sensors (p. 293, Introduction: "[R]ealistic tracking and classification applications involv[e] tens of thousands of sensors [having] heterogeneous sensing modalities…"; p. 298 col 2/par. 2 noting that sensor selection function depends on sensor type)

21. Claims 11-12 are rejected under 35 U.S.C. 103(a) as being unpatentable over Chu, Kuhn, and Edelkamp in view of Gelvin et al. (US Patent 6,859,831)

22. Chu teaches the invention substantially as claimed including use of constraint-based routing for optimal path selection in ad-hoc sensor networks (see Abstract)

23. Regarding Claim 11, Chu teaches the system of claim 4, including constraint-based routing for optimal path selection in an ad-hoc sensor node network (Abstract)

Chu, Kuhn and Edelkamp do not teach:

wherein the sensor nodes comprise acoustic sensors

Gelvin teaches:

wherein the sensor nodes comprise acoustic sensors (col 18/lines 37-44; The "sensors include seismic, acoustic, and infrared motion devices".)

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Gelvin regarding use of a particular sensor with those Chu with regard to managing a network of sensor nodes, since Gelvin simply teaches a specific embodiment using acoustic sensors.

24. Regarding Claim 12, Chu teaches the system of claim 4 including constraint-based routing for optimal path selection in an ad-hoc sensor node network (Abstract)

Chu, Kuhn and Edelkamp do not teach:

wherein the sensor nodes comprise seismic sensors

Gelvin teaches:

wherein the sensor nodes comprise seismic sensors (col 18/lines 37-44; The "sensors include seismic, acoustic, and infrared motion devices".)

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Gelvin regarding use of a particular sensor with those Chu with regard to managing a network of sensor nodes, since Gelvin simply teaches a specific embodiment using seismic sensors.

25. Claim 17 is rejected under 35 U.S.C. 103(a) as being unpatentable over Chu and Kuhn, in view of A. Stentz, *Optimal and Efficient Path Planning for Partially-Known Environments*, Conference Proceedings on Robotics and Automation, vol. 4, IEEE International, May 1994 (Stentz)

26. Chu teaches the invention substantially as claimed including use of constraint-based routing for optimal path selection in ad-hoc sensor networks (see Abstract)

27. Regarding Claim17, Chu teaches the method of Claim 13, including constraint-based routing for optimum path calculation (Abstract)

Chu and Kuhn do not teach:

finding a path that includes detours around sensor network holes and at least one path ending

Stentz teaches:

finding a path that includes detours around sensor network holes (obstacles) and at least one path ending (p. 3310, §1.0, "One approach to path planning in this scenario is to generate a "global" path using the known information and then ..."locally" circumvent obstacles on the route detected by the sensors... It is possible to generate optimal behavior by computing an optimal path from the known map information, moving ... along the path until either [one] reaches the goal or ... sensors detect a discrepancy between the map and the environment, updating the map, and then replanning a new optimal path from the .. current location to the goal"; p. 3313, §2.3

Illustrating operation of D* algorithm to provide detours around obstacles, by setting arc costs "prohibitively large" for obstacle cells)

It would have been obvious for one of ordinary skill in the art at the time of the invention to apply the teachings of Stentz regarding obstacle avoidance with the teachings of Chu and Kuhn regarding optimal path calculation and routing in an ad-hoc sensor network environment, since calculating a path that includes sensor network holes ("total obstacles") does not reach the destination.

Response to Arguments

28. Applicant's arguments filed 4/21/2009 with respect to rejection of claims under 35 USC §103(a) have been considered but are moot in view of the new grounds of rejection.

Conclusion

29. Applicant's amendment necessitated the new grounds of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any

extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to ROBERT SHAW whose telephone number is (571) 270-5643. The examiner can normally be reached on 9:30am- 6:30pm Monday-Thursday.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Saleh Najjar can be reached on (571) 272-4006. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/R. S./
Examiner of Art Unit 2455

/saleh najjar/

Supervisory Patent Examiner, Art Unit 2455